

SUITED AND UNSUITED HYBRID III IMPACT TESTING AND FINITE ELEMENT MODEL CHARACTERIZATION

C. Lawrence¹, J. T. Somers², M. A. Baldwin³, J. A. Wells⁴, N. Newby², N. J. Currie⁵

¹NASA Glenn Research Center, Cleveland, OH

²Wyle Science, Technology and Engineering Group, Houston, TX

³Lockheed Martin, Denver, CO

⁴Lockheed Martin, Houston, TX

⁵NASA Johnson Space Center, Houston, TX

NASA spacecraft design requirements for occupant protection are a combination of the Brinkley Dynamic Response Criteria and injury assessment reference values (IARV) extracted from anthropomorphic test devices (ATD). For the ATD IARVs, the requirements specify the use of the 5th percentile female Hybrid III and the 95th percentile male Hybrid III.

Each of these ATDs is required to be fitted with an articulating pelvis (also known as the aerospace pelvis) and a straight spine. The articulating pelvis is necessary for the ATD to fit into spacecraft seats, while the straight spine is required as injury metrics for vertical accelerations are better defined for this configuration.

Sled testing of the Hybrid III 5th Percentile Female Anthropomorphic Test Device (ATD) was performed at Wright-Patterson Air Force Base (WPAFB). Two 5th Percentile ATDs were tested, the Air Force Research Lab (AFRL) and NASA owned Hybrid III ATDs with aerospace pelvises. Testing was also conducted with a NASA-owned 95th Percentile Male Hybrid III with aerospace pelvis at WPAFB.

Testing was performed using an Orion seat prototype provided by Johnson Space Center (JSC). A 5-point harness comprised of 2 inch webbing was also provided by JSC. For suited runs, a small and extra-large Advanced Crew Escape System (ACES) suit and helmet were also provided by JSC.

Impact vectors were combined frontal/spinal and rear/lateral. Some pure spinal and rear axis testing was also performed for model validation. Peak accelerations ranged between 15 and 20-g. This range was targeted because the ATD responses fell close to the IARV defined in the Human-Systems Integration Requirements (HSIR) document. Rise times varied between 70 and 110 ms to assess differences in ATD responses and model correlation for different impact energies.

The purpose of the test series was to evaluate the Hybrid III ATD models in Orion-specific landing orientations both with and without a spacesuit. The results of these tests were used by the NASA Engineering and Safety Center (NESC) to validate the finite element model (FEM) of the Hybrid III 5th Percentile Female ATD.

Physical test data was compared to analytical predictions from simulations, and modelling uncertainty factors have been determined for each injury metric. Additionally, the test data has been used to further improve the FEM, particularly in the areas of the ATD preload, harness, and suit and helmet effects.